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ABSTRACT

This manual on solar heating and cooling systems is one of a series of individualized instructional materials for students. The manual is self-paced, but is designed to be used under the supervision of a coordinator or an instructor. The manual contains 15 assignments, each with all the information needed, a list of objectives that should be met, and exercise questions that can help in meeting those objectives. The assignments are organized into six sections. The first section introduces solar heating and cooling systems and explains how to use the manual. The second section suggests planning considerations for those considering solar conditioning, while the third section covers the various types of solar heating and cooling systems. The fourth and fifth sections of the manual cover the controls and plumbing needed for solar systems and the solar equipment needed. Installation and maintenance of solar energy systems are covered in the final section. A glossary and a bibliography are included in the manual. (KC)

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Introduction to Solar Heating and Cooling Systems

Student's Manual

D.O.T. 637.281 and .381

By
L. A. Grimes, Jr.

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Foreword

This publication is one of the Center for Occupational Curriculum Development series of individualized instructional materials for students. Each student who uses this material can work at his or her own pace, learning those things that best fit specific needs. The design of the material makes it possible to relate work experience on the job with information studied at school.

Although the material is self-paced, it should be used under the supervision of a coordinator or instructor. Two basic publications are offered—a student's manual and an instructor's guide.

The *student's manual* is for the person in training. It is self-contained. Each assignment has all the information needed, a list of objectives that should be met, and exercise questions that can help in meeting those objectives.

The *instructor's guide* has additional information that may help the instructor help the student. There are suggestions on how the student should use the student's manual and how the instructor can coordinate work experience and learning at school. The instructor's guide also contains (1) answers to both exercise questions and assignment test questions, (2) one set of assignment tests, and (3) a work sheet that the instructor can conveniently use to match related instruction to job experience for the student.

Although both publications are copyrighted, an instructor should feel free to reproduce copies of the assignment tests and work sheet. To make that possible, we have placed the tests and work sheet in a separate section of the instructor's guide, where they are readily accessible for copying. If the instructor prefers, copies of these same sheets for individual students can be ordered separately from Extension Instruction and Materials Center, P. O. Box 7218, The University of Texas at Austin, Austin, Texas 78712.

Jack E. Robertson, Ph.D.
Director, Extension Instruction
and Materials Center

Preface

Solar heating and cooling is one of the newest forms of energy systems and has gained attention with the realization that conventional energy sources may soon be exhausted. A great deal of time and effort has already been spent on developing various methods to tap this practically limitless source of energy.

This manual has been written for the primary purpose of introducing the student to the methods being employed to use this resource. Solar energy has been used for heating water for nearly sixty years, but solar space heating and cooling is only now beginning to be considered a viable alternative. The future for solar heating and cooling looks bright, and the sun could well be the primary source of energy in another twenty or thirty years.

L. A. Grimes, Jr.
Curriculum Specialist

A Special Note to the Student

The assignments in this manual are designed to help you learn. You will gain more from this material if you know how to work the assignments. For that reason, Assignment A-1 is about how to use this manual and should be completed first.

Section

A

**Introduction to Solar Heating
and Cooling Systems**

- A-1. Using This Manual**
- A-2. The Future of Solar Environment
Careers**
- A-3. Safety Using Solar Energy**

Objectives: After completing this assignment, you will be able to—

1. give the primary purpose for studying and answering questions contained in this manual;
2. discuss the reasons for assignment objectives;
3. discuss the procedures to use when studying the information part of the assignment;
4. discuss the uses of the assignment exercises and how the questions should be answered; and
5. tell how the assignment tests are used.

A-1

Using This Manual

Purpose of a Student's Manual

Student's manuals are designed to present related technical instructions, procedures, and illustrations to groups of trade and industrial students. They may also be used by other groups in which the learning levels of individual students vary considerably. They are not intended to be used as a type of correspondence course but must be used by students under the direct supervision of an instructor.

A student's manual is designed to be used by the student so skills may be enhanced in the classroom about the same time related operations are done on the job. For example, during the time students are installing solar panels on the job, they should also be reading and studying at school about the theory of the use of solar panels. This combination of backup training in theory and the actual work on the job gives the student well-rounded knowledge and experience about each specific operation.

Parts of an Assignment

Objectives. In order for the students to know what they should learn, each assignment begins with a list of objectives. Students should study the objectives before read-

ing the information part of the assignment. After finishing the assignment, students should read the objectives again to see if they have succeeded in meeting the objectives. Success is checked through the use of the exercise and the assignment test.

Information. All the information for each assignment is given in the assignment itself. The exercise and the assignment test for each assignment are based on the information in that assignment. The student should read all the information carefully before answering the exercise questions. Any illustrations should also be studied. Tools and materials may be illustrated in these figures, as well as certain procedures and operations. It is also wise to re-read during the exercise or after the assignment test has been taken any information that is unclear. Certain tasks on the job may make it necessary later to refer to the assignment information.

Exercise. The exercise questions are based on the information given in the assignment and are designed to help the student meet the objectives. The student should write both the question and the answer on a separate sheet of paper. The answer should be in the form of a complete sentence. If students own their own student's

manual, they may find the exercises helpful for study later. After the instructor has checked the answers to the exercise questions, students should correct any mistakes and place the papers in their notebooks. If the exercise questions have been answered correctly, the objectives stated at the beginning of the assignment have been met. The exercises in this manual are designed to make the student think. They do not contain any fill-in-the-blank, multiple-choice, or true-false questions. The student should consider each question carefully before writing an answer.

Test. The assignment test is a short quiz of four to six questions that may be answered very quickly. The test may be given as soon as the specific assignment has been completed, or several individual tests may be combined and given together during a testing period as a weekly or six-weeks' test. The assignment test questions in this manual are either fill-in-the-blank or multiple-choice questions.

Exercise

1. What does a student's manual present to the student?
2. What combination of training gives the student well-rounded knowledge and experience about each specific operation?

3. Name the four parts of each assignment.
4. When should the assignment objectives be studied?
5. What should the student do before trying to answer exercise questions?
6. What may be shown or detailed in the illustrations?
7. When is it sometimes necessary to reread information

- found in the assignment?
8. What is the purpose of the exercise questions?
9. In what form should the answers to exercise questions be written?
10. What should students do with the exercise questions and answers as soon as they have been checked by the instructor?

11. When may it be assumed that the assignment objectives have been met?
12. What are the exercise questions in this student's manual designed to do?
13. When may assignment tests be given?
14. What types of questions are found in the assignment tests?

A-2

The Future of Solar Environment Careers

Objectives: After completing this assignment, you will be able to—

1. give the duties of solar heating and cooling workers;
2. discuss the regions where solar workers are usually employed;
3. give the basic qualifications of people working with solar heating and cooling systems; and
4. discuss the future of solar heating and cooling.

Duties of Solar Workers

People whose job is constructing and installing solar heating and cooling systems in new buildings must be involved in all phases of planning and building. The solar energy system is different from conventional systems, so various parts of structures must be built accordingly. New types of equipment and components are necessary that are unfamiliar to workers of traditional building trades.

Solar energy workers must study heat stresses and how they affect individuals. They must take air movement, temperatures, and humidity into consideration before designing a system. During the planning stage, they must consider initial costs, operating costs, and tax savings.

These workers will install special insulation to make the best use of solar elements. They must take special precautions to protect exposed areas during cold weather. They work with active and passive systems using liquid-based and air-based space-heating systems. Their work includes knowing how to use and install controls and backup systems when sun energy is not available. They may install rock bins, evaporative coolers, absorption chillers, or use the

Skytherm system of putting bags of water on a flat roof. They are responsible for setting up solar water heater systems and pumps and fans to move air or water.

Solar energy workers will also set up and install filters, collectors, and shading devices. They will use all types of hand and power tools during installation. They must also know how to clean the systems and be able to maintain them after they have become operational.

Places of Employment

Although solar heating and cooling systems are being installed in all parts of the country, most of the employment will be in the southern and western parts of the United States. These regions are selected because of their greater number of sunny, cloudless days, which are necessary for the use of solar energy. At this time most solar companies are rather small, but they are expected to grow as reserves of other sources of energy become critically low.

Basic Qualifications

Persons going into solar heating and cooling work must have a basic knowledge of the overall construction of houses and build-

ings. This includes knowledge of carpentry, plumbing, electrical systems, sheet metal work, and masonry. They must be able to use complicated formulas in figuring heat loads and radiation effects on various materials. They must be able to read blueprints and be able to use hand and power tools typically used in the building trades. They should have good mechanical aptitude and manual dexterity.

Employment Outlook

The use of solar energy for heating and cooling has created a new field, but it has been slow in expanding. For that reason there are few people who are skilled and knowledgeable in it. The person getting in the field while it is new should have an excellent chance of moving up very fast. Surveys show that more and more residences and commercial structures will use solar heating and cooling as soon as products become available. The initial cost has been the largest problem up to this point, but other forms of energy are now becoming almost as expensive as solar energy systems. A qualified solar energy worker should have few problems in getting and keeping employment in this field.

Exercise

1. Why must the solar energy worker study heat stresses?
2. Why must workers install special insulation?
3. What systems will the worker be using?
4. What must the worker use and install to be used when sun energy is not available?
5. What must the worker be able to do after the system has become operational?
6. Where will most of the employment be?
7. Why must the solar worker be able to use complicated formulas?
8. Why should the solar heating and cooling worker be able to move up fast?
9. What has been one of the largest problems up to this point?

Safety Using Solar Energy

Objectives: After completing this assignment, you will be able to—

1. describe methods of keeping the system free of water and air pollution;
2. discuss the dangers of system leakages;
3. give the steps to take when cleaning the system; and
4. discuss problems related to noise and injury on the job.

Pollution

When working with solar heating and cooling systems, always be aware of any dangers of pollution. The main pollutants found in these systems come from the chemicals used in heat transfer, fluids used in heat pumps and air conditioners, materials used for washing collector fields, and lubricants used in mechanical devices. Some of these pollutants are necessary for the proper operation of the system, but accidental pollution can occur if necessary precautions are not taken.

Pump failure or transfer pipe blockages can cause temperatures to rise to the point that relief valves open, releasing vapors into the atmosphere and liquids to the ground. Holding tanks should be available to house any liquids that may be released. Pipes may also rupture under these conditions.

Leakages

Serious problems can arise if there are leakages in the walls or floors of the structure. Leaks can be dangerous if the system contains hazardous or toxic liquids. The leaking mixture could be anti-freeze, ethylene glycol, hydrocarbon, or high boiling oil. Fumes,

injection, or fire can take place under various conditions. Frozen pipes can cause leakage when the system is not protected during cold weather.

Operational Releases

It is often necessary to release some pollutants during the cleaning of a system. Solar heating and cooling systems should be cleaned periodically to ensure that the proper amount of liquid can pass through the system. The system is usually flushed out and cleaned with normal detergents, but the fluids in the system can be very dangerous if they are discharged into a septic tank or sewer system. If the materials are toxic or hazardous, they should be picked up by a waste disposal company.

Noise

Noise pollution is common in all heating and cooling systems and must be taken into consideration during construction. Noise insulation for pumps and fans should be thick enough to keep the system's operation from distracting the occupants. The location of these pieces of equipment also has a bearing on how much noise and vibration is transferred to the usable areas of the structure. Work-

ers should take precautions and use ear protectors when setting up and checking this equipment.

Injuries during Installation

Injuries in solar energy construction are very similar to those encountered by the typical building trades worker. The worker should always use goggles when flying sawdust, metal, or other particles can cause eye injuries. Falls are quite common. The installer should take care when working on the roof or climbing ladders. Working with a variety of hand and power tools that can cut, slice, or bruise the body is common. All safety rules should be followed in all of these operations.

Electrical shock is always possible. Do not work with live wires, see that equipment is grounded, and do not use faulty equipment or worn extension cords and wiring.

A particular hazard in this type of work is exposure to hot pipes or collectors. See that all of this equipment is well insulated before attempting to work around it.

Exercise

1. Where do the main pollutants found in solar heating and cooling systems come from?

2. What kind of pollution can occur if necessary precautions are not taken?
3. What may cause vapors or liquids to be released?
4. What should be used to catch released liquids?

5. What dangerous materials could be leaked into a structure during operation?
6. What could be dangerous during the cleaning of a solar heating or cooling system?
7. What should workers use for

protecting the ears during setup and equipment checks?

8. When should goggles be worn?
9. In what type of special hazard is the worker subject when working with solar heating and cooling systems?

Section

B

**Planning for Solar
Conditioning**

- B-1. Heat Stress on the Individual**
- B-2. Financial Considerations**
- B-3. Structural Design**

B-1

Objectives: After completing this assignment, you will be able to—

1. discuss how air temperature affects heat stress;
2. describe how air movement affects a person's perception of heat;
3. explain how humidity affects heat stress; and
4. discuss radiant temperatures and their effects on the body.

Heat Stress on the Individual

Air Temperature

Heat stress has a large effect on the temperament and working ability of most people. We usually define how comfortable we are in relation to the temperature of the air. If our house or office is 90°F, we consider it to be too hot for comfort and we suffer heat stress. If the temperature is 55°F, we feel that it is too cold to be comfortable unless we wear sweaters, coats, or cover ourselves with blankets. There is also the problem of heat stress differences in people. What is relatively comfortable for one person may be too hot or too cold for another. An in-between comfort zone or average temperature is usually decided on. The temperature may be controlled by some type of thermostat, which keeps the air temperature in a 5- to 10-degree range. A comfortable temperature range is also affected by air movement, humidity, and radiant temperatures.

Air Movement

Some people develop heat stress (either hot or cold) because of too much air movement or the lack of air movement. During hot weather, most people are more comfortable when the wind is blowing or if fans are used in a business or residence. This does not mean

that the temperature is changed, but the movement of air across the body reduces heat stress. The effect is the opposite if the air temperature is considered cold. Air movement then causes the person to feel uncomfortably cold and to suffer heat stress. These factors must be considered when planning what type of equipment to install for air movement.

Air movement is not always a solution to the problem of too much heat. If it is hot or the air temperature is high, excessive air movement may cause discomfort by drying out the skin. Excessive air movement may also cause a noise problem.

Humidity

Humidity has a considerable effect on comfort and heat stress. Too much humidity causes the individual to experience a "sticky" feeling or a feeling of closeness. It sometimes affects the lungs and the ability to take deep breaths. This is the reason evaporative air coolers are not successful in areas where rainfall averages are high. Likewise, not enough humidity in the air causes discomfort to the throat and nasal passages. Humidity level must be taken into consideration when heating and cooling systems are planned.

Radiant Temperature

Radiant temperature is what we receive when we are in the sun. Walking beneath a tree in the shade shields this radiation, and the person feels cooler. That is also why we prefer sunny places when the air is cold. The solar heating and cooling worker considers radiant temperature when working with the design of the structure. In order to give the occupant a cooler atmosphere, heat radiation must be kept from penetrating into the interior. If this is not entirely possible, the angle at which it enters may be altered, so that as little direct radiation as possible enters.

Exercise

1. How do we usually define how comfortable we are?
2. What factors will affect the temperature range in a structure?
3. How does air movement affect a person?
4. What may excessive air movement cause?
5. How does too much humidity affect an individual?
6. What may low humidity cause?
7. When do we receive radiant temperature?
8. How can we make adjustments to control heat radiation?

B-2

Financial Considerations

Objectives: After completing this assignment, you will be able to—

1. discuss the initial costs necessary for constructing a solar heating and cooling system;
2. give the operational costs involved in solar heating and cooling; and
3. show tax savings and credits that can be earned by installing solar heating and cooling systems.

Initial Costs

The initial costs of solar heating and cooling are rather high. Several factors contribute to this expense. The two main factors are the special design of the structure to house the system and the materials and equipment needed for collectors and storage units. Other costs may include absorption chillers, freeze protection, extra insulation, controls, and other equipment.

Most systems require a regular duct system for air transportation or pipes and vents for liquid transportation. In most localities a backup system is needed if there are not enough cloudless days. This means that most savings would have to be made up from the smaller use of electricity, gas, or other forms of energy dependent on petroleum products or nuclear systems. When comparing a solar heating and cooling system with other types of heating and cooling, any savings has to be figured from lifetime use. However, no concrete estimate can be made because the cost and availability of other types of energy in the future are unknown. It is known that petroleum products are being expended at a very fast rate and cannot be replenished. Experimentation with other types of energy

that could be replenished, such as wood or plants that could be cultivated especially for the purpose of supplying energy to the world, may or may not solve the energy problem. Coal is plentiful at this time, but the cost of mining and the impact on the environment may play an important part in its use. Most figures, therefore, include a lot of guesswork. However, experts generally agree that over the lifetime of a structure, there will be sufficient savings to warrant the use of solar energy.

Operational Costs

The best part of using solar energy for cooling and heating is the low operational costs. Continual daily use of other systems requires the replacement of parts and complete units fairly often. Furnaces usually last from fifteen to twenty years, and air-conditioning compressors are worn out as soon as five years to as late as fifteen years. These costs are extremely high. These systems may be used to back up solar heating and cooling, but their use is limited and the life expectancy when used solely in this way is much longer.

However, solar systems do require some repairs and replacement of parts at times. Active systems must be cleaned out,

which may require replacement of antifreezing elements. Pipes may eventually corrode and have to be replaced, or they may freeze and burst. Outside collectors and structures may have to be repaired or replaced.

Taxes and Credits

The federal government has recognized the importance of the use of other types of energy and has made it much easier for industry and individuals to install solar heating and cooling systems. Tax credits up to \$2,000 are allowed on certain types of solar equipment. Some credits are even allowed for backup equipment that is used with solar systems. There is also a business investment tax credit for those businesses using solar energy.

Many states have now enacted laws to give tax credits on solar energy systems. Some states subsidize loan programs to increase the construction of solar energy systems. Others exempt these systems from property taxes. Two examples of state programs are discussed in the following paragraphs.

Texas has enacted a law to exempt both solar and wind energy systems from real estate taxes. Another law allows a corporation

to deduct from its taxable capital the amortized cost of solar energy equipment over a period of five years or more. Another law allows a franchise tax exemption for companies that engage specifically in manufacturing, selling, or installing solar energy heating and cooling equipment.

California has a tax incentive that allows a personal income tax credit of 55 percent of the initial cost of a solar energy system up to a maximum credit of \$3,000. Multiple-family dwellings with costs exceeding \$6,000 are allowed 25 percent of the cost. The state also has a program of grants and loans to give \$2,000 interest-free loans for solar heating and hot water systems when a state of emergency

has been declared. The maximum loan to a veteran for a home mortgage is increased to \$60,000 when the residence is equipped with a solar energy system.

Exercise

1. What two main factors make the initial cost of solar heating and cooling expensive?
2. What is needed in localities where there are not enough cloudless days?
3. How must savings be figured when comparing solar systems with other systems?
4. What is the best part about using solar energy for cooling and heating?
5. What must be replaced on some solar systems because of cleaning?
6. How much federal tax credit is allowed on certain types of solar equipment?
7. What do some states subsidize to increase the construction of solar energy systems?
8. What exemption is allowed in Texas for companies that engage in manufacturing, selling, or installing solar energy heating and cooling equipment?
9. How much personal income tax credit is allowed for a solar energy system in California?
10. In California who is given maximum home mortgages up to \$60,000 when the residence is equipped with a solar energy system?

B-3

Structural Design

Objectives: After completing this assignment, you will be able to—

1. discuss how various house plans contribute to better solar heating and cooling;
2. give points to consider concerning air and liquid transport systems;
3. discuss insulation procedures to follow in a structure using solar energy; and
4. explain what protection must be made against freezing.

House Plans

Most houses using conventional heating and cooling systems today are not planned to save energy. One thing to consider when planning to heat and cool by thermal energy is the site for the structure and if building codes governing that site permit this type of system. Some zoning ordinances determine height and type of building. Check on sewer discharge temperature regulations because the system may be of the type that discharges hot liquids.

The solar energy system planner should know the direction of prevailing winds, average temperatures, and average rainfalls. Average number of cloudless days is also important, because the design of the system and structure will be controlled by the sun's relation to the site.

The planner must specify the number of square feet in the structure and know how each room is to be arranged. Conventional systems do not require such critical planning because larger furnaces or air conditioners may be used to offset problems that result from inadequate planning. Solar energy systems cannot afford that luxury because only so much heat or cooling can be obtained and stored.

If the solar collector is installed on the roof of a structure, additional braces are needed to sup-

port the extra weight. Special flashing must also be used to prevent liquids from leaking into the structure. The roof collector design must be taken into consideration, because the collector may make the structure look unbalanced or there may be danger of exposing it to the wind during stormy weather. The structure must also be designed so that snow cannot collect in it. Also, the system must be designed so that the collector can be easily removed for cleaning.

Air and Liquid Transport Systems

The elements of air and liquid transport systems will be covered in detail later, but it should be pointed out that the locations of pipes may differ from those in conventional systems. Air passage ducts may also vary. The locations of vents must be planned carefully so conditioned air is in the best possible location for temperature control.

Passive systems are particularly sensitive to air movement throughout the structure. Windows or other openings using outside light must be planned carefully because a great amount of heating and cooling can enter through windows that are too large or that are located at the wrong place in relation to the sun.

Insulation

One of the most important aspects of solar heating and cooling planning or installation is adequate insulation in the structure. There are several available insulation materials. Glass fiber, rock wool, plastic foams, and reflective foil laminates are the most common types in use. Care must be taken that walls and ceilings have the proper thicknesses of insulation and that they are well sealed at all edges. If the insulation tends to "pack down" or settle after a period of time, more insulation should be added.

It is also important that insulation strips and seals be used around doors and windows. A lot of heat and coolness can pass through a very small opening. Even electrical outlets should be insulated to prevent air from passing through the slots for plugs. The metal box can be filled with insulated foam.

Thermal panes should be installed in all windows and glass doors. Storm windows and doors also give more protection.

Freezing

Special consideration must be given to thermally heated and cooled structures in areas where freezing occurs in the winter months. Much

time and expense can be wasted if proper precautions are not taken. All liquid-carrying pipes must be wrapped with insulation materials, and some type of antifreeze must be used to keep the water from freezing and bursting the pipes. Any holding tanks are also subject to freezing.

Exercise

1. What do some zoning ordinances determine?

2. What should you know about the weather when planning a solar installation?

3. What is needed when installing the solar collector on the roof of a structure?

4. To what are passive systems particularly sensitive?

5. What are the insulation materials commonly used for solar heating and cooling?

6. What should be done if insulation "packs down"?

7. What should be used to insulate electrical outlet boxes?

8. What type of panes should be installed in windows and doors?

9. How are liquid-carrying pipes and holding tanks protected from cold weather?

Section

C

Heating and Cooling Systems

- C-1. Active Systems
- C-2. Passive Systems
- C-3. Cooling Systems
- C-4. Hot Water Conditioning

C-1

Active Systems

Objectives: After completing this assignment, you will be able to—

1. discuss liquid solar space heating and cooling systems; and
2. explain the operations involved in air solar heating and cooling systems.

Active solar energy systems depend on some mechanical means of forcing the circulation of liquids or air over a solar-heated surface. Solar space heating and cooling is a relatively new field, and many types of solar installations are being used. Many applications of solar energy are still in the experimental stages. As time passes and extensive tests are made, there will probably emerge some consistent forms of systems that will allow manufacturers to mass-produce components at an economical price.

Liquid Systems

Solar systems using liquid may be similar to conventional systems or use a fan and coil system, air convectors, or hydronic radiant panels. One liquid system makes use of a central forced-air furnace similar to that used in conventional systems. A water-to-air heat exchanger is placed in the furnace plenum or return air duct. The hot water from a storage or holding tank is forced to the heat exchanger by a circulating pump. The pump is operated by a thermostat in the structure. When the air from the solar heat exchanger is not sufficient, the furnace is turned on to supply the needed heat.

A fan-coil system consists of metal pipe containing hot water.

A fan is used to blow air over the heat exchanger pipe coil. It also has a thermostat to control the amount of heat needed. The liquid in the coil may be water or a water and antifreeze mixture. Steam can also be used. If the system is used as a space cooler, chilled water is used in the pipe coils. Backup equipment for the fan-coil system may be operated with electricity, gas, oil, or coal. Sometimes electric strip heaters are used in air ducts as a backup. Apartments may require individual fan-coil units and thermostats.

Forced-air convectors consist of a heat exchanger with several sections of tubing containing metal fins. Hot water is forced through the tubing in specially built units. The units contain a fan that blows the air over the fins and on into a room in the building or house. Some convectors have no fan, but transfer heat by natural convection and radiation similar to steam radiators that were used in office and apartment buildings and schools for many years.

Hydronic radiant panels consist of a series of copper tubes that are placed in floors or ceilings. These tubes contain solar-heated water that comes from a solar storage tank. The water circulates continuously during the time of year it is needed. Backup heat for the

water is usually obtained from a conventional hot water heater.

Air Systems

There are several advantages to using air-based active solar energy systems for heating and cooling. Primary advantages include no freezing problems, no water leaks in the system, lower installation cost, and no danger of pressure buildup in the pipes.

Disadvantages of the air systems include the need for a large storage space for a rock bin, the required use of heat exchangers, and the economic unfeasibility of air systems when they are used with many solar coolers.

There are several types of successful air heating systems. An example is the Solaron air system, which pulls air through a collector array and heats it. This air then passes through a duct housing to an air-to-water heat exchanger. The water is warmed in a preheater tank. A backup system heats the water further if necessary. The warm air is forced through the ducts to the specific vents being used.

As mentioned earlier, rock bins are also used for heat storage on some systems. Some storage facilities also use water-filled plastic bottles placed in an insulated location.

Exercise

1. What do active solar energy systems depend on to circulate liquids or air?
2. When using a central forced-air furnace, where is a water-to-air heat exchanger placed?
3. What forces the hot water from a storage or holding tank to the heat exchanger?
4. What is used in the heat exchanger pipe of a fan-coil system?
5. What is used in the pipe to make a space cooler?
6. How do convectors with no fan transfer heat?
7. Where are hydronic radiant panels placed in a structure?
8. What are the advantages of using air-based active solar energy systems?
9. Where does the air in the Saron air system go after it is pulled through the collector array?

Passive Systems

Objectives: After completing this assignment, you will be able to—

1. discuss the economy of using a solar passive system for heating and cooling; and
2. explain various methods used to direct heating and cooling to various parts of a building.

Economy of Passive Systems

Passive solar heating and cooling is very economical, mainly because of its use of the sun's rays coming in the structure through glass and the use of rock bins or other natural storage devices. Fans are about the only mechanical devices used in passive systems.

Passive Designs

Figure 1 gives an example of one passive design. The rays of the sun either strike the glass or are

reflected from an aluminum or light-colored surface. The structure has glass on the south side and large windows to trap the rays. Water-filled plastic bottles are heated, and the air is pulled over them and on through air ducts into the room space. Then it cycles back to the heated space in back of the windows. Meanwhile, the glass on the lower level heats the air in back of it, and a fan pulls the heated air into the rock bin below the floor. This warm air then travels through an air duct

back up to the lower space in the building and is ready to circulate again. The rocks in the bin and the water-filled bottles are soon heated and store heat to be used at night.

Another method of passive heating is shown in figure 2. A thick concrete wall is painted a dark color so that it will absorb the sun's rays. It is usually about 2 feet thick and faces south. A double glazing of glass is placed outside the wall with a space of about 4 inches between the glass and the wall. The air flows in the duct

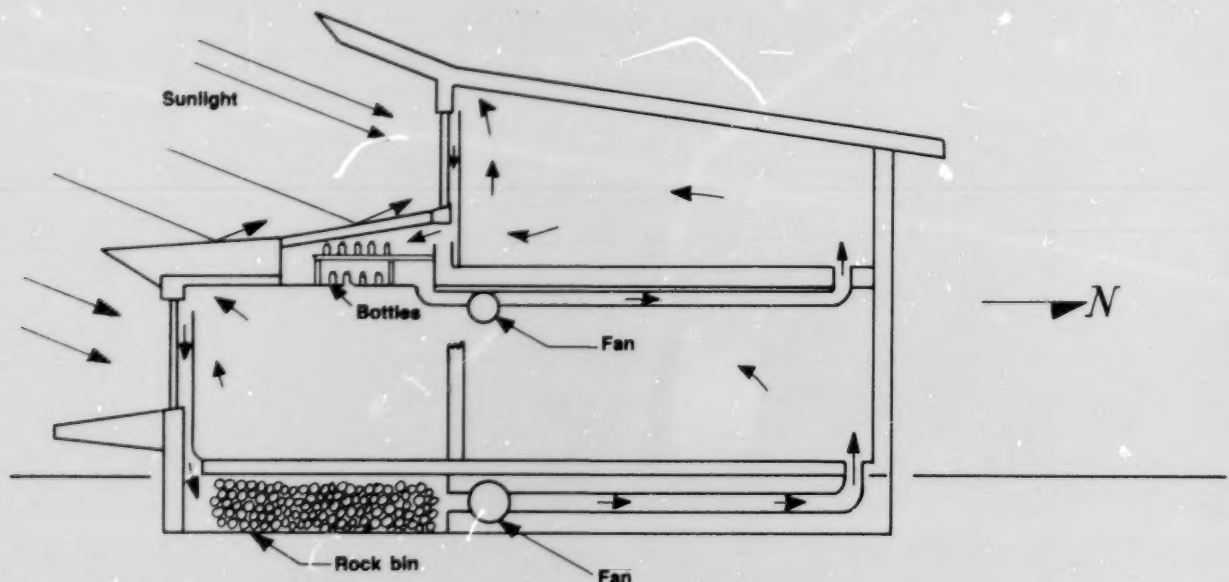


Fig. 1. Using water-filled bottles and a rock bin

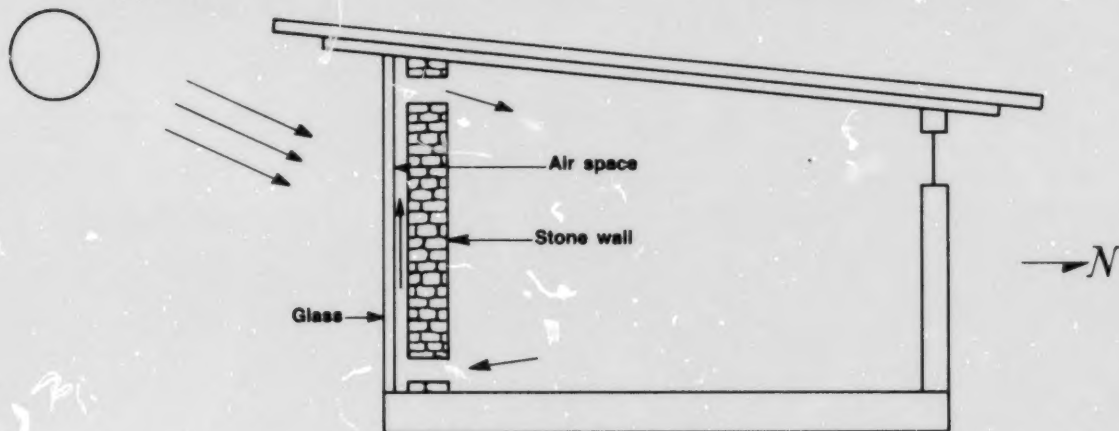


Fig. 2. Using a masonry wall for heat storage

between the glass and wall. The cool air is pulled by convection through openings at the bottom of the wall. As the air is heated by the sun through the outer glass, the air rises and is pulled through openings near the ceiling.

The wall also retains the daylight heat from the sun. At night, the air vents are closed by dampers to keep outside air of lower temperature from being drawn through them. The heat retained in the wall then gives off enough heat to keep the structure warm during the night. This design can also be used for cooling.

Other passive systems include

the use of skylights, either fixed or louvered; plastic sheets used in aluminum frames with large water-filled plastic tubes or cylinders behind them retaining the heat generated; and earth-heated cavelike homes made with stone masonry walls. When you begin working with solar-heated buildings, you will find that dozens of methods can be used to capture and circulate the heat. Most are effective to a certain degree, and many combinations can be used to achieve an efficient system. When building passive systems, you should always be sure to utilize the maximum benefits of sunlight entering the building.

Exercise

1. What are the only mechanical devices usually found in passive systems?
2. What are the reasons for using water-filled plastic bottles?
3. Why does one system use a thick concrete wall painted a dark color?
4. What does convection do to the air?
5. What is done at night to keep the heat in and cool air out?
6. When a thick wall and glass are used for capturing heat, how much space is allowed between the two?
7. What should be utilized when building passive systems?

C-3

Cooling Systems

Objectives: After completing this assignment, you will be able to—

1. describe the use of rock bins as a cooling method;
2. discuss the use of the Skytherm system;
3. explain how absorption coolers are used; and
4. discuss the use of a Rankine engine powered by solar energy.

Rock Bins

As mentioned before, a rock bin is used to store both warmth and coolness. Using a rock bin for cooling is more efficient in the western states where the air is cool at night. The cool air is brought into the house and flows over the stones until they are cool enough to furnish coolness during the day. Some systems use blowers to pull the air through. Others have small air conditioners that cool the stones at night.

There are several things to remember when building a rock bin. The unit must be strong enough to support the weight of the stones. It can be constructed from wood or concrete. Often the rock bin is poured as part of the building's basement. However, the rock must always be insulated from the concrete at the floor and walls. Rigid foam insulation is often used. If wood bins are constructed, they must also be insulated. They are usually of 2-by-4 board and plywood construction, but it is wise to overlap the plywood for a good seal. Steel mesh should be used to support the rock. An example of a rock bin is shown in figure 1.

The stones should be from 1 to 1½ inches in diameter and should be carefully washed before they are added to the bin. If they are not washed, dust will be blown into the system. Be sure that the box is sealed, except for the air

inlet and outlet. A sensor must also be placed in the bin at the lower part of the unit. This indicates the temperature of the rocks and tells the owner whether the rocks have reached the proper temperature. It is best to protect the sensor from damage by placing it in a conduit or PVC (polyvinyl chloride)—plastic—tube.

The Skytherm System

The Skytherm system is used for both heating and cooling. It consists of transparent plastic bags that are placed on a flat roof and filled with water. Each bag is about 8 feet wide and 38 feet long and filled with about 9 inches of water. A transparent sheet of ultraviolet-

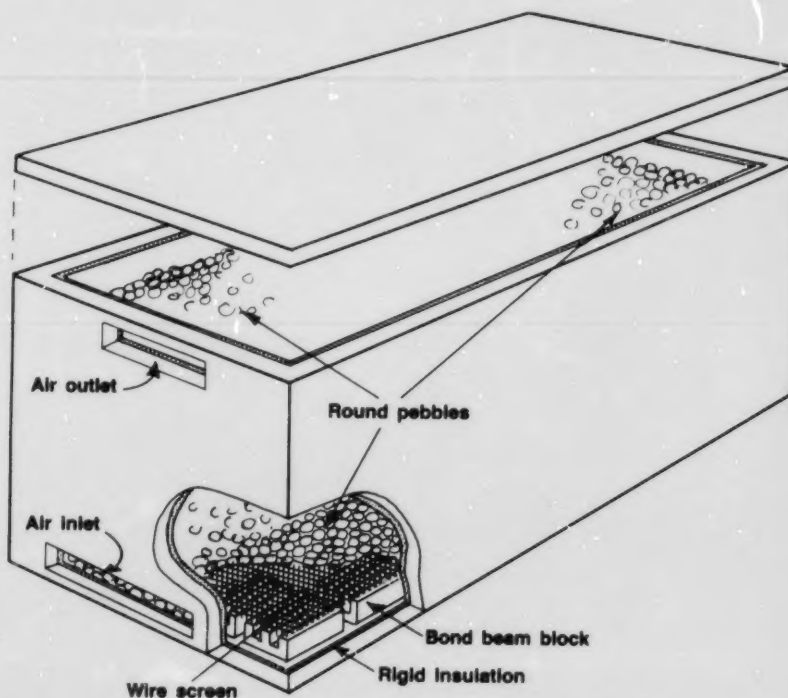


Fig. 1. A rock bin unit

resistant PVC is sealed to the edges of each plastic bag and is suspended about 2 inches above each plastic bag by air pressure. A black PVC sheet is placed beneath each bag and acts as the solar radiation absorber.

For summer cooling, the plastic sheets above the water bags are placed in direct contact with the water bags. The bags are covered during the day with insulating foam panels. At night, the bags full of water lose heat energy by radiation and convection. The next morning the water and metal ceiling below the bags are cooled, and the air circulation brings in cool air.

Absorption Coolers

A system using absorption coolers consists of heating water by thermal energy and using it to operate absorption chillers. Water is usually heated to about 240°F at the

collector outlet and pumped through a collector flow loop to a heat exchanger in the equipment room. This thermal energy is transferred to another high-temperature loop. There is an auxiliary gas or electrical hot water heater at this location that is used when the temperature is not high enough. This high-temperature water supplies enough energy to operate the absorption chiller. The chilled water is then circulated through fan-coil units to cool the building.

Rankine Engine Cooling

The solar system using Rankine engine cooling, in practical terms, is a heat pump that is driven by solar energy. It uses liquid system solar collectors, an engine, heat pumps, centrifugal pumps, and thermostatic controls. The heated vapor is used to drive the engine, which can be used for both heating and cooling.

Exercise

1. What are rock bins usually constructed of?
2. What is used to support the rock in the bin?
3. What size stones are used in a rock bin?
4. What is placed in a rock bin to indicate the temperature of the stones?
5. What is placed in the bags of a Skytherm system?
6. What is done during the day to the bags to give summer cooling?
7. What is used to operate absorption chillers?
8. What auxiliary equipment is used if there is not enough hot water or the temperature is not high enough?
9. What is Rankine engine cooling—in practical terms?
10. What other equipment is needed for Rankine engine cooling?

C-4

Objectives: After completing this assignment, you will be able to—
1. discuss the various types of commercial solar water heaters; and
2. describe the operations of a solar water heater.

Hot Water Conditioning

Solar water heaters have been used for many years in the western part of the United States. Contrary to popular opinion, they are not particularly expensive and are very efficient. Some solar water heaters were built as early as 1923, but

many have been installed since the forties. If someone wanted to build his or her own design, there are many books with step-by-step procedures giving details of basic materials and parts needed.

The Joule box solar water heater

is an example of the many similar types of solar water heaters that are built commercially. Figure 1 outlines how this model is built. The solar collector contains a black aluminum absorber plate and copper tubing that transfers the hot

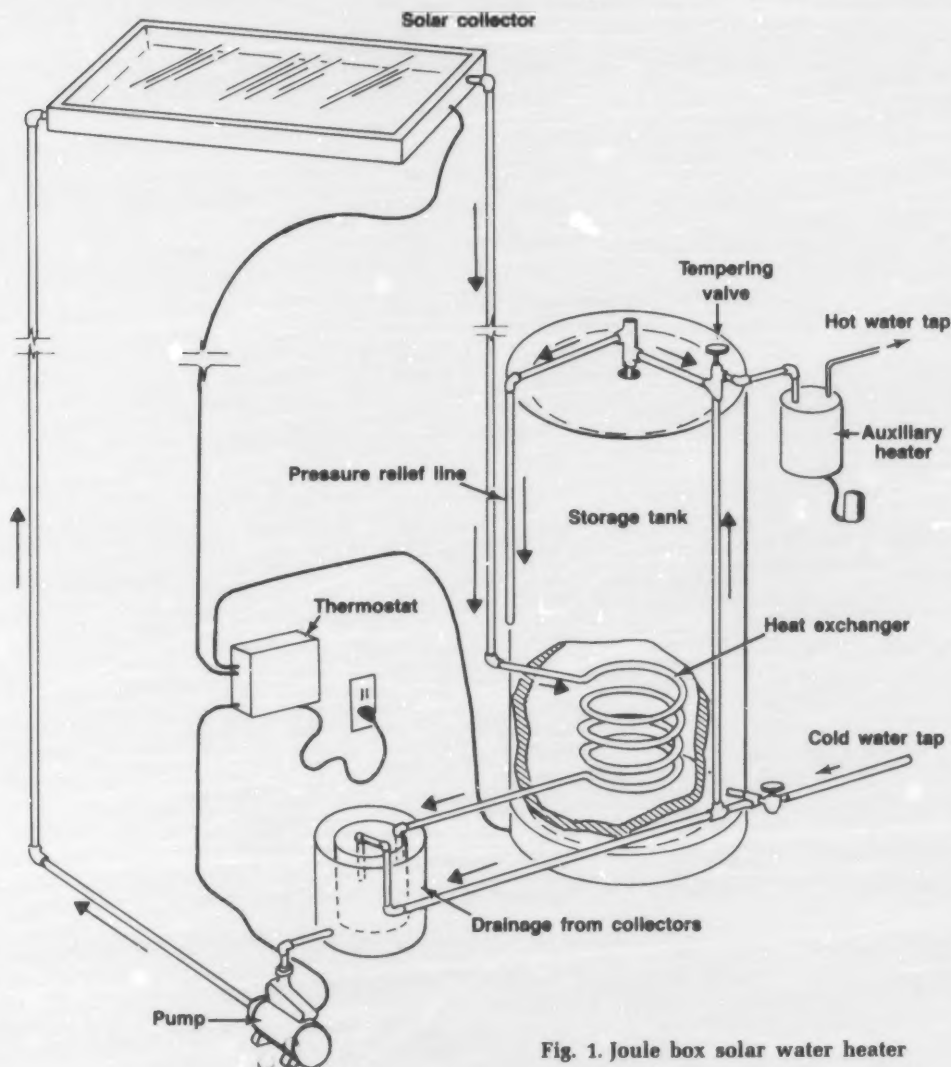


Fig. 1. Joule box solar water heater

liquid through 3/4-inch flexible tubing to coils in the stone-lined and insulated storage tank. It is a closed system until the liquid leaves the storage tank, draining into a smaller tank. From the small tank it is pumped back up to the solar collector for recirculation. The coils in the large storage tank act as a heat exchanger by heating the cold tap water in the tank. An auxiliary heater is attached between the storage tank and the hot water tap to be used when there is not enough sunlight to keep the water in the storage tank hot. A thermostat is used to turn the pump off and on automatically.

One type of solar water heater does not have a thermostat or pump. The system is operated by

a thermosiphoning system. The system requires the tank inlet to be located higher than the top of the solar collector so that siphoning can take place. An electrical unit is usually added to give supplementary heat when sunshine is not available. This system costs much less than other types.

Many imported systems use a black plastic collector panel, although most built in the United States are made of metal. The metal systems cost more but are usually more durable.

The efficiency of solar water heaters depends to a great extent on the type of collector used. Because collectors are discussed later, they are not covered in detail here.

Exercise

1. How early were solar water heaters built?
2. What lines the Joule box solar water heater storage tank?
3. What acts as a heat exchanger in the Joule system?
4. What turns the pump off and on automatically?
5. What system does not contain a thermostat or pump?
6. Why does that system require the tank inlet to be located higher than the top of the solar collectors?
7. What type of collector panel is used by many imported systems?
8. On what does the efficiency of solar water heaters depend?

Section

D

Controls and Plumbing

D-1. Controls

D-2. Pumps, Valves, and Pipes

Objectives: After completing this assignment, you will be able to—

1. describe the functions of automatic controls for solar heating and cooling systems;
2. discuss the operations of differential thermostats; and
3. explain how sun tracking controls are used.

D-1

Controls

Automatic Controls

Many types of controls are used in the various solar heating and cooling systems. An automatic control eliminates many problems, since a person cannot always be available to make adjustments. If the water heater is conventional and has a mixing valve on the output side, a thermostat set to monitor high temperatures is not usually necessary. If the storage tank is not of this type, a sensor must be placed in the upper part of the tank to prevent unusually hot water from going into the hot water system. The mixing valve is a safeguard against allowing water as high as 160°F from being introduced into the hot water tap.

All solar energy systems must have at least two sensors. One sensor indicates the temperature of air or water that comes from the solar panels on the roof. The other indicates the temperature of either the air in a rock bin or the water in a storage tank. Some systems also have sensors for ambient or environmental temperatures and temperatures of the heated space in the building.

Differential Thermostat

A differential thermostat is used to control the heat of a storage tank throughout a 24-hour period. It automatically turns the pump off or on when the temperature

reaches certain points. There is no use for a pump to be running if it is not necessary. The pump is usually off from about 6 P.M. until 8 A.M. but is needed during the daylight hours. When the pump is turned on, cooler water in the storage tank uses heat from the collectors, and the temperature drops for a short time. In the afternoon the temperature of the outlet water from the collectors drops fairly close to the storage temperature. The water at this time is still being heated by solar energy, so there is some rise in temperature, but not usually enough to start the pump again.

This type of thermostat control has a hysteresis, or lag feature, that keeps the pump from being turned on every time there is a brief fluctuation in temperature. This control saves a lot of unnecessary wear on the pump and pump motor.

One type of differential thermostat does not completely shut the flow of water on and off. It changes the amount of flow when there is a change of temperature. This type of thermostat keeps a more even level of temperature, but operating the pump more increases cost and causes more wear.

Sun Tracking Controls

Sun tracking controls are operated through the use of photovoltaic

sun sensors. These are solar cells that are placed about 60 degrees apart. When the sun rises, the signal level from the cells turns on a motor drive system. It turns the unit until the collectors are placed perpendicular to the rays of the sun. The solar tracker is locked in to these rays and follows them throughout the day. These trackers are operated on low voltage, so the cost is minimal.

Exercise

1. When is a thermostat set to monitor high temperatures not necessary?
2. What must be placed in the upper part of a tank that has no mixing valve?
3. Why is a mixing valve usually necessary?
4. What are the uses for four sensors in some systems?
5. What is the primary use of a differential thermostat?
6. What is the purpose of a hysteresis or lag feature in a differential thermostat?
7. When is the pump ordinarily shut off?
8. What is the advantage of the type of differential thermostat that changes the flow but does not cut off the pump?
9. What type of sensor is used to track the sun?
10. What do the sun sensors do when the sun rises?

D-2

Pumps, Valves, and Pipes

Objectives: After completing this assignment, you will be able to—

1. discuss what to consider when installing a pump in a solar heating and cooling system;
2. give the types of valves and their purposes; and
3. discuss pipe materials, sizing, and support.

Pumps

When ordering a pump for a solar heating and cooling system, the installer should give the manufacturer certain information so that the proper pump can be furnished. Knowing how much fluid is to be pumped through the system and what size pipes are to be used is essential. Also, 90-degree turns will affect the flow, and having many turns may require a larger pump or a motor with more horsepower. There must be adequate net positive suction head at the pump inlet or cavitation (an air cavity in the line) will occur.

Impeller materials used in the pump are also important. A cast-iron impeller may be used in "dead" water without encountering problems. But if air is dissolved in the fluid, impellers made of bronze or stainless steel should be used to eliminate most corrosion problems. If glycol solutions are used in the circulatory system, galvanized pumps should not be installed.

Priming can be a problem when the system has been shut down and must be started again. Non-priming pumps should be located so that the prime can be maintained. If you have an open system in which this problem may arise, place the pump inlet below

other points in the system. This keeps a positive pressure at the inlet.

Valves

A large variety of valves are needed in any solar heating and cooling system. Various parts of the system must be isolated during different phases of a cycle or during repairs and adjustments.

Gate-and-ball valves are used to isolate components such as collectors, pumps, heat exchangers, and storage tanks when they have to be removed from the cycle for various reasons. These valves are also used for draining or filling the system. One thing to remember is the type of seals in the valves. Special seals are needed if the system contains high-temperature solvents such as silicone working fluids or glycol solutions.

Always use a relief valve in any part of the system that can be isolated by other valves and where heat can be added. This safety feature should not be overlooked because pressure can build up and cause serious damage or even injury.

Mixing valves are used in some solar energy systems. The temperature of the water can become very hot during summer and if allowed to go through the tap, the

user could be scalded. The mixing valve mixes enough cold water with the hot to reach a fixed temperature at the tap.

Flow control valves are used when each circuit of the system is connected in parallel. Equal flows must be maintained, and these valves keep the flow system in balance. Most flow valves have both inlet and outlet pressure taps. Be sure that flow rates in collector loops do not exceed the regular flow rate because this irregularity could cause erosion in the collector tubes. Sometimes flow meters are installed so that if a valve is accidentally closed, a flow problem will be noticed. Otherwise, pressure could build up and cause a serious problem.

Safety valves are used to control any pressure or temperature buildup. A safety valve must always be placed where it will not be deactivated for any reason. For instance, one placed where it could freeze in cold weather would be of little use to a system during a typical winter. If there is a release by a safety valve during the operation of the system, the release must be at a safe location. If the material released could be toxic, it should go into a holding tank rather than a sewer tank. Any liquid or steam should be routed outside the structure.

Check valves are used to stop any reverse flow in the pipes. There are two types of check valves. One type has a spring that causes it to close. The other works by gravity. There will be a lower pressure drop when the spring type is used, but small particles of foreign matter can hold it open. When gravity-powered check valves are used, they are used in a horizontal or vertical position. A reverse flow is caused by low pressure from a gravity flow, rather than the pump. To be certain that the riser to the collector loop from the collector pump can be drained, installers place check valves between the drain and the fill fitting.

Solenoid valves are used in more complicated systems. They

should not be used unless completely necessary because they are expensive to maintain and do not have long-term reliability. They are used mostly on commercial and industrial systems. They are placed in operation by controllers when there is a tendency for fluids to leak through the valves or if fluids must be rerouted.

Pipes

Pipes in solar cooling and heating systems are usually made of copper or steel, although more and more systems are using plastic pipes. Many plastic pipes are not usable when temperatures rise above 140°F, so be sure to know the maximum temperatures of the fluid going through the pipes.

Never use galvanized pipe because any temperatures above 130°F will remove the coating, allowing the zinc to dissolve into the liquid passing through the pipe.

If you are using copper tubing, be sure that it is either soldered with a 95/5 solder or soldered with silver to keep it from being affected by high temperatures.

Pipe sizing is affected by the size of the system, type of pump, and number of turns in the pipe. Most manufacturers have charts to show what sizes will be needed.

Be sure all pipe is properly supported. Sagging pipe will affect the efficiency of the system. Take care that all piping is properly insulated because freezing is a common problem.

Exercise

1. What may many 90-degree turns in the pipe do?
2. What may occur if there is not adequate net positive suction head at the pump inlet?
3. Of what materials should the impeller be made if air is dissolved in the fluid?
4. When should galvanized pumps not be used?
5. If you have an open system in which priming problems may exist, where should you place the pump inlet?
6. What components are gate-and-ball valves used to isolate?
7. When are special seals needed in gate-and-ball valves?
8. What valves are used to keep the water from being too hot at the tap?
9. When are flow control valves used?
10. Where should any steam or liquids released by safety valves be routed?
11. What is the purpose of check valves?
12. What causes a reverse flow?
13. What materials are normally used for pipes in solar energy systems?
14. What affects pipe sizing?

Section

E

Solar Equipment

- E-1. Filters, Collectors, and Shading
Devices**
- E-2. Heat Exchangers, Absorbers, and
Dampers**

Objectives: After completing this assignment, you will be able to—

1. discuss the use of filters in a solar heating and cooling system;
2. give an example of a type of solar collector in use today; and
3. give the purpose of using shading devices during part of the year.

Filters, Collectors, and Shading Devices

Filters

Solar heating and cooling systems, like conventional systems, must be equipped with filters. Filters must be used in both liquid and air systems. The accumulation of various types of foreign material can hamper either liquid or air flow and cause overheating of the collector, pump, or fan.

Filters in air systems reduce or eliminate dust and other airborne particles that can cause discomfort or activate allergies of the occupants of a commercial building or home. Filters in the air system also help keep the rock bin clean.

Liquid systems use filters to collect pipe sediment, metal chips, or dirt that is in the system when it first goes into operation or that is introduced during maintenance or repair later. A strainer is sometimes used in a liquid system when it is first started because there will probably be more waste products in the pipe at that time than later. After the system has been cleaned, a regular filter can be used for normal operation.

Solar Collectors

Although many types of solar collectors are used today, there are only basically two physical principles at work in collecting solar

energy. First, there should be a dark surface exposed to the sun so that solar energy can be absorbed. The second principle is the use of transparent glass or plastic that admits short wavelengths of the sun's energy but does not allow the reradiated energy that has been captured to escape. The energy is then contained between the glass and the dark surface.

There are two basic types of passive collection. The first type uses the overhang of the roof to direct the sun's rays into the structure in the cold months. Curtains, drapes, and insulation are used at night or on colder, cloudy days to hold the heat inside. Sometimes containers of water are arranged at the windows to absorb the sun's rays and radiate the heat throughout the building. The concrete wall that was mentioned earlier is a variation of the same technique, except that the wall, instead of the bottled water, absorbs the heat.

The second method of passive collection uses the roof as a collector. Room air flows along beneath the heated roof, is warmed, and then goes into the living space by means of a thermosiphoning effect. Another variation of passive collection transfers energy by using water containers painted black to heat the living space by reradiation and convection. For cooling,

insulated panels are placed over the containers during the day and removed at night so that the water will be chilled.

Active solar collection makes use of forced circulation of air or liquid over a solar-heated collector. A simple flat plate collector is shown in figure 1. It consists of a flat steel, aluminum, or plastic plate or sheet that has been painted black or another dark color. Tubes are fastened to or above this plate. They will house the fluid flow. The underside of the absorber plate is insulated so that the heat will be held in one location to heat the liquid in the tubes. The collector is covered with a sheet of glass or plastic to keep the heat from escaping. There is a fluid inlet in one end of the unit and a fluid outlet at the other.

There are dozens of commercial collectors on the market, and it would be impossible to describe each. They all contain the basic principles found in the flat collector, but some use different materials or have curved designs with different types of insulation.

It is important that a structure have enough collectors to give sufficient heat or coolness. A number of variables affect the decision of how many collectors to use. The geographic location of the building is important, because that

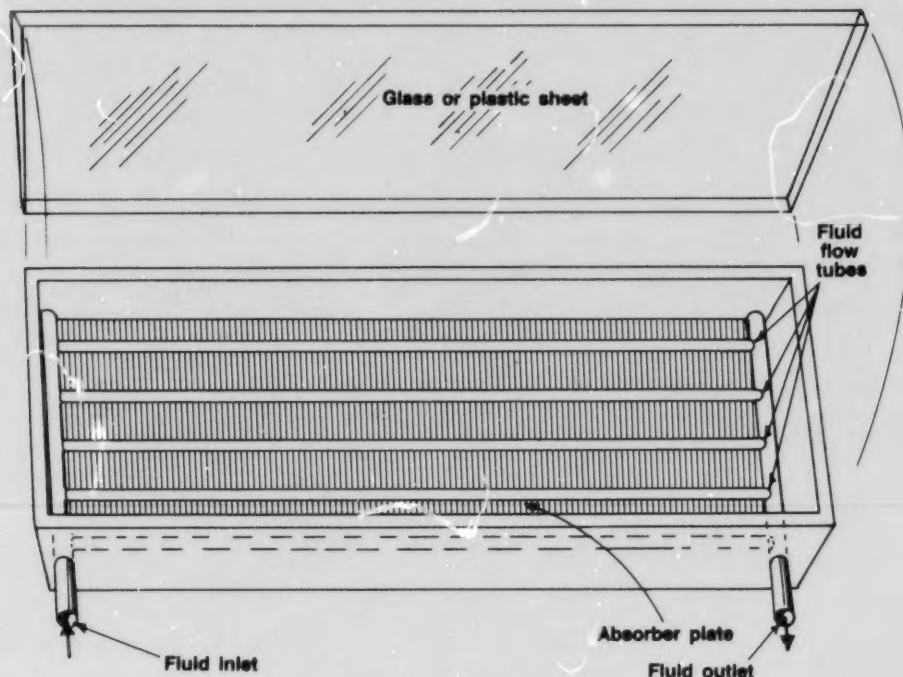


Fig. 1. Flat plate solar collector

should indicate approximately how much sunlight will be available. The design of the collector panels is also important, because some panels are larger or more efficient than others. How many people will occupy the house, the building will also affect how many collectors will be necessary. If the collectors are to furnish heat for a water heater as well as for space, the demands for heated water by the structure's occupants also need to be considered.

Shading Devices

Shading devices are needed to keep the sun's rays from penetrating the windows or heating the solar collectors in the summer. Most collectors have insulated pan-

els that are easily fastened or slid above the collectors when needed. The outer surfaces are usually light in color so that as much heat as possible is reflected away from the collectors.

The shading device should be lightweight for ease in handling, but also tightly secured so winds will not knock it loose. It must be able to withstand damp weather and be designed so that no moisture can be trapped between the panels and the collector.

Trees should not be planted near the collectors, because they will interfere with the sun's rays after they have grown to full size. Some cities have zoning laws that prevent the planting of trees on lots where they could cause shade to fall on another person's solar collector.

Exercise

1. What is sometimes used in liquid systems to collect waste products when the system is first put into operation?
2. What are the purposes of a filter in an air system?
3. Name the two main physical principles at work in collecting solar energy.
4. What are the two basic types of passive collection?
5. What are the basic parts of a simple flat plate collector?
6. Why is the collector covered with a sheet of glass or plastic?
7. What determines the number of collectors needed?
8. How are collectors usually shaded?
9. Why should the outer surfaces of shading devices be painted light colors?

Objectives: After completing this assignment, you will be able to—

1. discuss the types of heat exchangers and their differences;
2. describe the materials used in absorbers and how absorbers are installed; and
3. name the various dampers used in solar energy systems and describe checks to make during their installation.

Heat Exchangers, Absorbers, and Dampers

Heat Exchangers

A heat exchanger is usually a coil of copper tubing that transfers heat from solar-heated water in the exchanger to the surrounding water in the storage container. Basically, the heat exchanger is used to isolate glycol solutions coming from solar collectors from water that is to be taken from a storage tank and used in a regular tap or water heater. The heat transfer takes place between the inlet on one side of the storage tank and the outlet on the other side. There is usually very little heat loss during this transfer. The larger the size of the heat exchanger, the smaller the temperature difference required to heat the water to a specific temperature.

There are three main types of heat exchangers. The *shell and tube* heat exchanger has an outer casing or shell that surrounds a number of tubes. The water to be heated is usually circulated in the tubes, and the hot liquid is circulated in the shell. Toxic liquids cannot be used for heat transfer to tap water because if there is a leak, and the liquids combine, toxic water would be passed into the water supply of the commercial building or residence. This type of heat exchanger can be used safely for space heating.

The *shell and double tube* heat exchanger is similar to the shell and tube exchanger, except that it has an extra chamber in the shell. Because the extra chamber encircles the tube, there is no danger of getting toxic materials in the tap water. A dye is often used in the toxic liquid to alert the user in the event of double failures.

A *double wall* heat exchanger has a coiled tube that is wrapped around and welded or soldered to a tank. The toxic liquid can be circulated either through the tube or in the tank. Either way they are separated. The weld or solder helps transfer the heat more efficiently.

Absorbers

Almost every commercial supplier of absorbers has a slightly different type of product. The primary purpose of absorbers is to catch the sun's rays and to transfer this heat to pipes or tubes that are directly on or welded to the plate. Reynolds Metals uses finned absorber plates. Each strip is about 6 inches wide, and the finned plate contains the tubing. The plate is made of aluminum and painted flat black.

The Solaron Corporation makes an absorber with a steel absorber panel that is coated with a highly absorbent black ceramic coating.

The air channels are made with steel pipe. This air-flow system passes the air below the absorber plate and above the insulation.

Solar Bond absorbers are made of two copper sheets that are bonded together. Long narrow strips in the sheets that are not bonded are then pushed apart down the length of the panel to make waterway channels.

Some absorbers are plated with black chrome and black nickel because of these metals' ability to withstand elevated temperatures. They also lose less heat than other metals.

One type of absorber that is imported from Israel has an absorber plate and piping made of galvanized steel and coated with a special black paint with above 90 percent absorption qualities.

Here are some things to remember: Aluminum plates are hard to repair if leaks develop; they must be removed for repair. Copper tubes can usually be repaired on the structure. Tubes work better if they are soldered or welded to the absorber plate rather than clamped. Some heat is lost when clamps are used.

When installing the absorber plate, leave a small space on all four sides because the great amount of heat absorbed causes

the metal to expand. Also use at least 1/2 inches of insulation below an absorber plate. Aluminum foil on top of the insulation helps to reflect the heat back to the absorber.

Dampers

Air flow in air systems is regulated by dampers. Back draft dampers prevent the air flow from going through selected flow loops if it is not needed. A motorized damper operates with actuators from control signals and changes the flow of air from one loop to another. Be sure the dampers have good seals because the high temperatures may cause leakage if unsuitable seals are used.

Dampers should contain good-quality shafts, shaft bearings, and adjustable linkages. Poorly made dampers can result in early breakdowns, system leakage, or coil freeze-up. Fire dampers should also be installed in air system ducts. Always adjust the dampers so they fit properly. Check for leaks by feeding scented air into the system.

Exercise

1. What is a heat exchanger?
2. What change is made if the size of a heat exchanger is increased?
3. Name the three types of heat exchangers.

4. Why is a dye sometimes used in the toxic liquid?
5. What does a finned plate absorber also contain?
6. What materials are used in the Solaron absorber panel?
7. Why are some absorbers plated with black chrome and black nickel?
8. What type of plate is hard to repair if leaks develop?
9. How should tubes be fastened to the absorber plates?
10. What regulates air flow in air systems?
11. What may happen if poorly made dampers are used?
12. How can you check for damper leaks?

Section

F

Installation and Maintenance of Solar Energy Systems

F-1. Installation and Maintenance of Solar Energy Systems

F-1

Installation and Maintenance of Solar Energy Systems

Objectives: After completing this assignment, you will be able to—

1. give the general requirements to consider when constructing a solar heating and cooling system;
2. discuss the construction details of a solar energy system; and
3. explain the procedures to follow in maintaining a solar heating and cooling system.

General Requirements

Location and Access. Always check all building codes in a city or area before beginning the job of planning and installing a solar heating or cooling system. No portions of the system should be located in any fire separation areas. The system should never interfere with the operation of other movable parts of a building such as doors or windows. Check city codes if the system requires any extension over public property.

There should always be a certain amount of clearance between a solar energy system and other materials—especially those that are combustible. If system components heat to as much as 250°F, leave a clearance of at least 1 inch. If the temperature may reach between 250°F and 500°F, leave a clearance of 6 inches. As mentioned earlier, see that there are at least 2 inches of insulation material beneath the absorber plate.

Protection. The entire system should be protected against penetration by water. Flashing and caulking must be added where there are any openings in the roof or wall. Be sure that all pipe and tubing joints are secure. If they are soldered or welded, they should be carefully checked under pressure before any walls or areas are closed.

There should also be protection against rodents and insects. All cracks and holes must be sealed. If any part of the system extends to ground level, use termite shields to keep termites from entering the structure. Special care must be taken if the rock bin is constructed of wood and is at basement level.

Collector protection is vital. Collectors produce high levels of heat. The combustible parts in the collector should be well insulated. Be sure that all parts of the collector are secured against wind damage. Also, the collector's cover panels should be strong enough to resist moderate hailstorms.

Structure

Some collector systems are quite heavy. Know the weight of any parts that are to be placed on the roof so that adequate braces may be used to support the weight. Keep in mind that there may also be snow loads in the winter. Remember to include the weight of the liquids that will be flowing through the collector tubes. Also be sure that any storage tank in a basement or that is buried is secured so that it will not float in case of flooding.

Never use material for braces that is of poor quality or might fracture under heavy loads. Woods

with open or loose knots should not be used. Nails should be of proper size.

Electrical. When cutting holes and notches in structural members for electrical wires, be sure not to weaken the structure. All wires and cables should be soldered and wrapped at joints, and no wires should be placed near parts where high temperatures may be generated. Do not connect fans or motor pumps into circuits in which overloading could occur. It is best to have a separate circuit for any electrical components to the solar backup system. Always ground all electrical equipment and circuits. Keep wires away from any corrosive elements in the solar energy system. Use only specified wiring when wiring must be used in ducts or other spaces where air will be passing over it.

Mechanical. Because solar energy systems use vapors, air, and liquid in the process of space cooling or heating and water heating, precautions should be taken with the elements being used. Toxic materials are often used in liquid systems to keep water from freezing. Take proper precautions when handling these materials, and see that they are sealed to prevent injury to building occupants. Pressures and heats should be carefully controlled. Relief valves must be

installed as safety devices in case of malfunctions. Always allow for both liquid and metal expansion when heat is involved. Freeze protection should be checked before the system goes into operation and checked periodically after that.

Check all seals against leakage. All valves and dampers must be in good condition. Use the scent test to check dampers.

Other Structural Precautions

See that all storage tanks and holding tanks are leakfree. Also, use heat exchangers that allow no possibility of contamination of the tap water by toxic materials. Rocks, stones, or pebbles that are used in rock bins should be washed free of any organic material before placement. They should be checked periodically to see that no fungi have attacked the rock. See that water and moisture cannot get to the bin.

At times liquid systems must be drained and cleaned, or an anti-freeze solution changed or added. An easy method of drainage should be incorporated into the construction with provisions for emptying the used liquids into a holding tank.

Be sure that there are warning lights to indicate any malfunctions in the system. In case of system shutdowns, be sure that safety devices are installed to handle the buildup of heat or pressure that can easily occur.

Always use pipes and tubes of sufficient size and of proper material. Use enough pipe supports to keep the line from sagging. Seal around pipes traveling through walls or other structures. Be sure they are insulated. Areas contain-

ing hot pipes should have warnings posted to keep an occupant or worker from being burned. This advice also applies to absorption plates. All food and drinks for human consumption should be kept away from pipes or other areas where fumes or leakages could cause contamination.

Installing the System

Whether the system is a do-it-yourself project or done by professionals, specifications and standards should be prepared before the system is started. Because active collectors are often placed on the roof of a residence or commercial building, an opening must be cut in the roof. Make provisions for protecting the rest of the structure while the unit is being installed. The collectors are usually installed first, and then the ducts and pipes are added. If walls or foundations have to be removed or reworked, be sure proper bracing, even if temporary, is added until the new structural additions are made.

After electrical, plumbing, and duct work has been completed, be sure that all insulation is installed. Pumps, valves, pipes, and dampers should be checked before the system is closed in. Inspect the system step-by-step, or have an expert check it before it becomes operational.

A maintenance schedule should be set up, also. A checkoff list is very helpful and will eliminate guesswork and the possibility of damage to the system or injury to the occupants. Also, include on the list any emergency procedures to be followed in case of a serious problem.

Exercise

1. What should be checked in a city or area before beginning the installation job?
2. How much clearance should be allowed if the system components heat to temperatures between 250°F and 500°F?
3. What should be done at any openings in the roof or wall?
4. When should pipes and tubing be checked for leakage?
5. What protection should be used if any part of the system extends to the ground level?
6. What should be done if there are combustible parts in the collector?
7. When bracing the roof to support collectors, what weights should be known?
8. What materials should not be used for braces?
9. How should electrical wires and cables be fastened?
10. What type of valves must be used as safety devices?
11. What types of expansion should you allow for?
12. Why should rock bins be periodically checked?
13. What should be installed to indicate any malfunctions in the system?
14. Why should an easy method of drainage for liquid systems be constructed?
15. What should be remembered about food and drinks around the solar heating and cooling system?
16. What should be done if walls or foundations have to be removed or reworked?
17. What should be done before the system becomes operational?
18. What should be set up for the occupants after the system is in operation?

Glossary

- Absorber plate**—a plate made of metal or plastic and painted a dark color (usually black) that absorbs heat from the sun's rays.
- Absorption chillers**—a refrigeration system used for solar cooling and powered by solar energy.
- Accumulator**—a small tank installed on the return pipe of a circulation pump of a liquid solar energy system. It is placed near the storage tank and allows for water expansion and contraction.
- Active system**—a solar heating and cooling system using forced circulation of water or air over a solar-heated surface.
- Ambient temperature**—the temperature of the surrounding atmosphere at a particular location.
- Automatic damper**—a device controlled by a thermostat that cuts off air flow to or from a room.
- Auxiliary energy system**—a backup system that uses conventional forms of energy. It is used as a supplement or when sunlight is not available.
- Cavitation**—an air cavity in a pipe carrying liquid.
- Collector, solar**—a panel composed of an absorber plate, tubes, and a glass or plastic cover. The collector absorbs solar radiation and converts it into thermal energy.
- Component**—a specific part or device that forms part of a more complex system.
- Conventional water heater**—a commercially produced hot water heater that is powered by traditional forms of energy such as oil, gas, or electricity.
- Fire separation area**—any open exterior space that is required for access to or for protection of a building or house.
- Flow meter**—a device used to measure collector energy delivery to other parts of the system.
- Forced-air convectors**—units consisting of a heat exchanger and tubing with fins. A fan blows air over the fins.
- Glycol solution**—an antifreeze solution to keep solar liquid systems from freezing.
- Heat exchanger**—usually a coil of copper tubing that transfers heat from solar-heated water in an exchanger to surrounding water in a storage container.
- Heat transfer fluid**—a liquid or gas used to transfer heat from one medium to another or to transfer thermal energy from one part of a system to another.
- Holding tank**—a tank used to hold toxic liquids that are drained from the solar energy system during cleaning operations.
- Hysteresis**—the time lag feature on thermostats that controls response to changing temperatures or other forces.
- Impeller**—the blade of a rotor that is usually found in a liquid-carrying pump.
- Inhibitor**—a chemical that is placed in the pipes or tubes of a liquid solar energy system to prevent corrosion of the pipes or tubes.
- Passive system**—a type of solar energy system in which solar energy comes into the structure through glass and is stored in rock bins or other natural storage devices. Fans are sometimes used to move the conditioned air.
- Photovoltaic**—specific materials that generate electrical energy when exposed to the rays of the sun.
- Plenum**—an enclosed space where the pressure is greater than the atmosphere, such as in an air duct. This causes air movement.
- Potable**—suitable for drinking, such as most tap water.
- Priming**—to start the flow of water or other liquids through a pump.
- Radiation**—the process of transmitting energy in rays from one surface across space to another surface.
- Rankine cycle**—the expansion cycle of a gas transported into a structure such as a turbine engine. The gas is compressed, then expands to create energy.
- Reflective loss**—light rays or energy that hits a surface and, rather than being absorbed, is reflected away.

Rock bin—a wood or concrete structure holding small pebbles or stones that is used in producing heating or cooling in a solar energy system. Conditioned air flows over the stones and is stored for later use.

Selective black paint—paint reputed to absorb more long infrared wavelengths of sunlight than other paints.

Sensor—a device used to measure temperature.

Solar energy system—a complete assembly of parts, controls, equipment, and an air or liquid flow system that converts solar energy to heat energy for heating water and heating or cooling space.

Storage tank—a large tank used for storing water and containing a heat exchanger to transfer heat from the solar collector to the water in the tank.

Thermal panes—panes with a double thickness of glass with a layer of air between. They are valuable as insulators.

Thermosiphoning—the natural upward movement of heated fluid through pipes or tubes. This method of movement is used for solar hot water heating when a pump is not used.

Thermostat—an electrical control that produces a signal to a switch when a temperature has reached a preset point. In a solar energy system, it may trigger a switch to a pump or fan.

Toxic—a property of gas or liquid that can produce either death or illness when inhaled, ingested, or absorbed through the skin.

Valve—a mechanical device that controls the movement of air, gases, and liquids by stopping, releasing, or regulating their flow.

Bibliography

Cowan, Henry J. *Solar Energy Applications in the Design of Buildings*. London: Applied Science Publishers, 1980.

Greeley, Richard S.; Ovellette, P.; and Cheremisinoff, Paul N. *Solar Heating and Cooling of Buildings*. Ann Arbor, Mich.: Ann Arbor Science Publishers, 1981.

Kreider, Jan F. *The Solar Heating Design Process: Active and Passive Systems*. New York: McGraw-Hill, 1982.

Lucas, Ted. *How to Use Solar Energy*. Pasadena, Calif.: Ward Ritchie Press, 1977.